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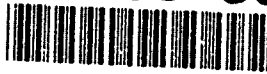
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Economic, Organizational, and Institutional Impact of the Survivability Validation Process

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13. ABSTRACT *(Maximum 200 words)*

This paper addresses some of the key economic, organizational, and institutional issues associated with the development and use of survivability validation protocols. It discusses factors affecting protocols, considerations for protocol selection, test-bed/simulator/analysis tool availability, organizational issues affecting protocol use, deviations precluding adherence to validated protocols, and protocol advantages. Knowledge of these factors will assist developers of survivability validation protocols in designing more flexible protocols that can be tailored for differing circumstances without losing the fidelity or assurance that the protocol will produce the desired survivability level.

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SUMMARY

The countries of the world are undergoing rapidly changing economic and political events. In addition, the United States defense budget continues to be under pressure to provide greater efficiency with fewer resources. To accomplish this the managers of large defense programs must use innovative and effective management procedures. One technique that will assist the Program Managers in this monumental task is the use of regimens and validated protocols to plan a survivability validation program. The program management team can select the approach best suited to their program, in order to provide the desired confidence in the system survivability within the schedule and financial constraints.

This paper addresses some of the key economic, organizational, and institutional issues associated with the development and use of protocols. It discusses factors affecting protocol cost (both development and application costs), considerations for protocol selection, test-bed/simulator/ analysis tool availability, organizational and instutional issues affecting protocol use, deviations precluding adherence to validated protocols, and protocol advantages. Developers of protocols should be aware of these issues. This knowledge will assist them in designing more flexible protocols that can be tailored for differing circumstances without losing the fidelity or assurance that using the protocol will produce the desired survivability confidence level.

Using validated protocols will provide extensive savings of time and resources during the program life-cycle, primarily due to the use of pre-approved systematic methods to obtain the prescribed hardness levels and associated confidence required for the system deployment. However, there are several outstanding issues that will be considered during the development of the protocols. These are listed below.

(1)   An adequate list of commercial and government test facilities, standards, handbooks, data items, and available analysis/simulation codes must be updated and configuration control must be imposed and maintained for as long as the database is utilized. This will be the basis set for the protocols and will be used by Program Office personnel in developing the survivability regimen. The basis set will include only validated protocols. Thus, community acceptance of the validation techniques will be easier, because the protocols are already in general use;

(2)   A determination must be made as to the level of generality of the protocols required to make a viable set of protocols for all types of situations. Protocols from each of the DoD agencies should be used and various techniques specific to a particular agency must be incorporated. This will also assist in acceptance of the protocols;

(3)   The resistance of agencies against adopting a new management technique must be addressed. This can be accomplished by informing the community through conference papers, technical meetings, and reports addressing the advantages of using protocols. Support for the new management technique can be obtained by inviting the interested agencies to workshops to assist in developing some of the protocols. This protocol introduction process must show the Program Managers that they will be provided with enough information to perform efficient cost/confidence trade-offs during protocol selection. In addition, it must be shown how the protocols will help the Program Office with hardness assurance, hardness validation, and hardness maintenance/hardness surveillance (HM/HS).

(4)   Investigations are required as to the best methods available to validate the survivability of a system that cannot be tested, such as a system that has widely separated components. Once the techniques have been established, the protocols can be developed.

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SECTION 1

BACKGROUND

This paper outlines the economic, organizational, and institutional factors involved in the survivability validation process. This section will introduce the basic protocol concept and the Program Office's view of survivability. The remaining sections will discuss protocol cost development factors, cost considerations for protocol selection, organizational and institutional issues affecting protocol use, deviations precluding adherence to validated protocols, and protocol advantages. The last section will provide a summary and list of suggested tasks to assist in protocol development. (This section utilizes all the listed references. Where material is taken directly from the text the reference is annotated.)

The new Integrated Weapon System Management concept being implemented by the various DoD agencies empowers a single manager with maximum authority over the widest range of weapon system program decisions and resources. Thus, the Program Manager will have the responsibility for the system during its entire life-cycle. A typical system life-cycle is depicted in Figure 1-1. The implementation of this concept will provide a single face to the operational commands to cover all aspects of integrated weapon system management from "cradle to grave," with initiation no later than Milestone 1 and lasting until the system is retired or canceled. Some of the major areas that Program Managers must be concerned with include:

(1) defining the system/facility requirements based on operational concepts and intended usage;

(2) interfacing between program management, specification development, design development, installation development, validation testing, and users throughout the duration of the program;

(3) identifying hardness elements, how they function, and their potential degradation modes. This includes the interrelationship of hardness with system/facility operation, configuration control, reliability, and maintainability;

(4) validating the survivability of the system through a combination of tests, simulations, and analyses;

(5) integrating hardness into system/facility design, fabrication, acceptance, operation, and maintenance;

(6) developing requirements, approaches, and procedures for maintaining hardness. This includes the role of hardness maintenance for the following areas: periodic inspections, repair activities, repair part validation, and inclusion in technical manuals;

(7) utilizing various techniques/procedures to conduct a hardness surveillance program and evaluate hardness element performance by performing inspections and testing;

(8) identifying support and test equipment to perform hardness assurance, hardness maintenance, and hardness surveillance;

(9) providing hardness technical data for system operation/manuals;

(10) identifying skills and manpower required for hardness assurance;

(11) defining system/facility maintenance and operation to provide hardness assurance;

(12) developing plans for hardness maintenance and hardness surveillance;

(13) instituting personnel training in hardness awareness, maintenance, and surveillance.
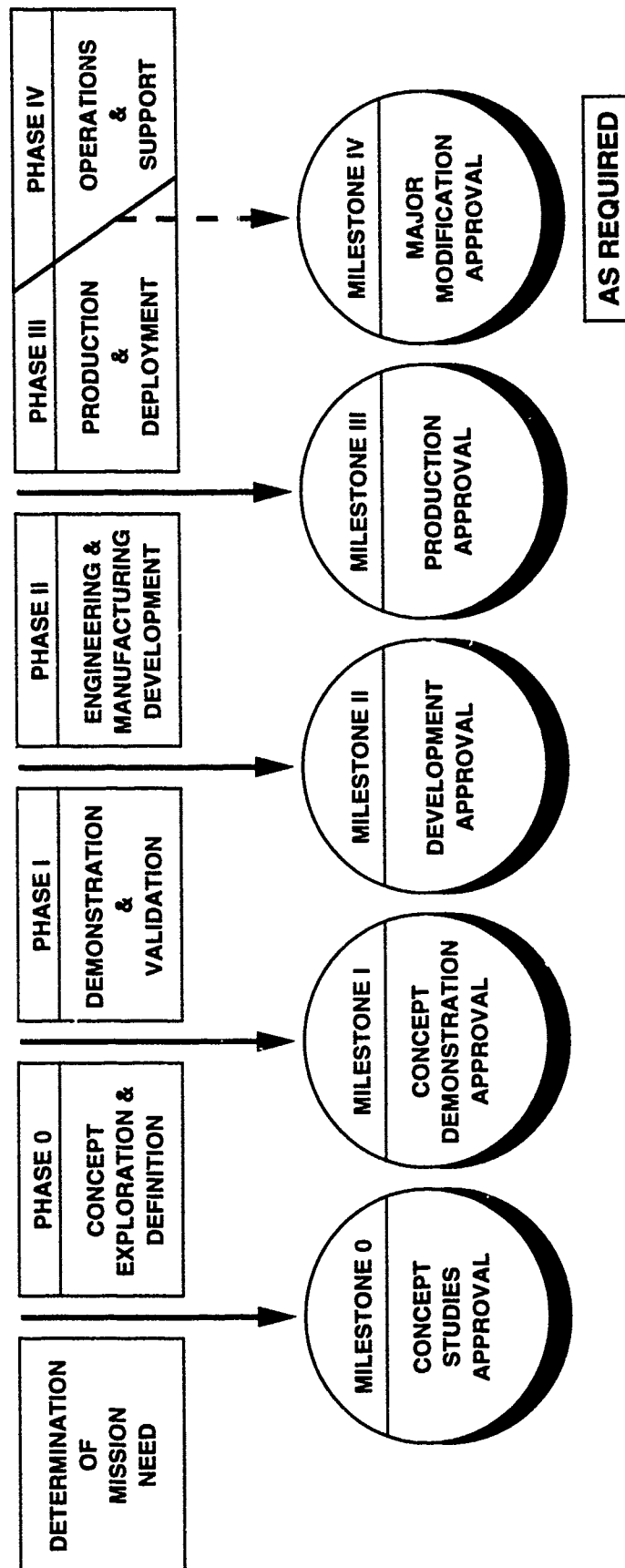
Figure 1-1. Acquisition milestones and phases.

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To assist the Program Manager in adequately performing these functions for survivability, an innovative management technique is required to streamline the survivability validation process. This management tool is effectively provided by the use of protocols.

A survivability validation protocol is a pre-defined, ordered set of tools and procedures that must be applied to a specific object to validate, with a measurable statistical confidence, the capability to perform a specified mission function in a defined environment resulting from a specified threat class. Application of the protocol to the specific object produces a documented collection of data establishing audible traceability through the system survivability validation process. A regimen is defined as a set of survivability validation protocols required to assure the specified performance of the system for its validated threat. The survivability regimen would be defined in the Test and Evaluation Master Plan (TEMP) by the Program Management Office and would be approved by the acquisition authority at Milestone 1. It should include sufficient detail to ensure the timely availability of both existing and planned test resources required to support the test and evaluation program. The TEMP is refined throughout the acquisition cycle at each of the milestones to provide increased accuracy for the survivability validation process and assure the system survivability. This necessitates a more detailed description of the tools and test procedures used to assure survivability.

SECTION 2

FACTORS AFFECTING PROTOCOL COSTS

2.1 INTRODUCTION.

To be an effective management tool, the cost of developing and applying a protocol must be kept to a minimum. Any new validation tools required to perform the protocol must be considered as part of the protocol development. Any deficiencies in the protocols or the validation tools must be identified as early in the acquisition cycle as possible. Enough lead time should be provided for the development of the components necessary for the protocol. If this is not done, then the hardness validation process will become the critical path in the system development. In some cases, the required protocol components may require a longer development time than the system being designed in the acquisition cycle. For example: if the mission requirements for a system indicate that underground testing (UGT) is needed, but a ban is imposed on underground testing, then a simulator might be developed to fill the need. The acquisition process for the simulator may take as long or longer than is allocated in the schedule of the system requiring the testing. For this case, other analyses or tests that provide a reasonable hardness confidence level would need to be performed until the simulator is available.

Initially, there will be some nonrecurring costs incurred in the development of the protocol formats and establishment of the databases. But as the protocols are utilized, only the cost of developing a new protocol and insertion of it into the database will be incurred. However, some of the factors impacting the development and application costs of a new protocol are listed below and will be addressed in the following paragraphs:

(1) complexity of system to be hardened;
(2) level of detail of analysis or test;
(3) magnitude of threat and deployment environment;
(4) complexity/sophistication of protocols;
(5) database development and configuration management of applicable standards and specifications;
(6) survivability confidence limits;
(7) cost of producing and validating needed software analysis tools;
(8) protocol application costs.

2.2 COMPLEXITY OF SYSTEM TO BE HARDENED.

The protocols in a regimen will address the different levels of integration from the highest level, a "system-of-systems" (SOS), to the lowest levels incorporating piece-parts and materials (refer to Table 7-2). The protocols can range from simple instructions, such as what military standard can be used to validate the survivability of a component, to a detailed end-to-end simulation of system-of-systems, such as a GPALS. A protocol can refer to testing, analysis, simulation, or a combination of these techniques to perform the survivability validation. As the system becomes more complex, the more detailed the protocol must become so as to be confident of the system survivability.

The protocols for the lowest level in Table 7-2, the part/material level, have been under development for many years and are fairly well defined. As new parts are developed, better processes are discovered to produce existing parts, or threats

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change, new protocols may be required to address these areas. The protocol development to evaluate the hardness of piece-parts would typically require minor modifications to the existing protocols in the database.

As the complexity or size of the system increases, the modifications to existing protocols become less straightforward and may require the development of entirely new protocols. Unless the the system is utilizing a totally new technology, enhancements to available protocols can be made as mentioned earlier for the piece-parts.

The regimen and protocols for system-of-systems could be built upon or include the protocols utilized for the lower level systems in the hierarchy of levels (see Figure 8-2). However, the regimen must contain the procedures to evaluate the interconnection of the components and the composite system as a whole. If the system requires an entirely new protocol, the requirement for the protocol development should be identified as early in the procurement cycle as possible.

2.3 LEVEL OF DETAIL OF ANALYSIS OR TEST.

The level of detail of the analysis or test must be considered in the development of a new protocol. For example, a protocol referring to a test method in a military standard will require less development time to implement than a detailed mathematical calculation using the latest method-of-moments techniques for coupling of an electromagnetic wave to a cavity of arbitrary shape. Validation of the survivability can be performed by many methods to include similarity of the components to other previously tested components or use of previously tested components, actual testing at expected threat levels, analysis using estimated threat levels, and simulation of the threat and/or system components. The method selected is dependent on the survivability confidence level required by the acquisition authority.

2.4 MAGNITUDE OF THE THREAT AND DEPLOYMENT ENVIRONMENT.

The threat to be countered and the projected deployment environment will be defined during the process of identifying the mission needs or deficiencies. In addition, a system threat assessment will be performed prior to each milestone decision point. The assessment will address projected capabilities that a potential enemy could use to defeat, destroy, degrade, or deny the effectiveness of a proposed concept or system being developed or produced. The System Threat Assessment Report (STAR) is prepared by the various DoD components and it contains the Defense Intelligence Agency validated threats. The STAR is the basic authoritative system threat assessment tailored for and focused on a particular defense acquisition program. In addition, the STAR is updated during each acquisition phase as determined by the milestone decision authority.

The types of threats (nuclear effects, kinetic energy weapon effects, directed energy weapon effects, or other electromagnetic weapon effects) and the scenario will determine the complexity and hence the cost of the protocols developed. For example, systems to be used in a tactical nuclear environment may not require the same level of protection or survivability confidence levels as systems used in a strategic nuclear environment. Thus, the protocols to validate survivability for each type of environment may have some similarities, but they may differ in the level of hardness or confidence level required for the system to survive in the anticipated environment. Likewise, the number of threats to be countered by a system will

determine the complexity and number of the protocols in the regimen to validate survivability of the system.

The protocols for air, land, sea, and space environments can have some similarities, but each will have requirements peculiar to that environment. Thus the protocols for systems to be deployed in a specific environment must be tailored to meet the survivability assurance levels of that environment.

2.5 COMPLEXITY/SOPHISTICATION OF PROTOCOLS.

As mentioned earlier, a protocol can be as simple as referring to a specific test procedure to validate the hardness of a component or it can be a complex simulation code to mimic a nuclear engagement. As the use of sophisticated software/hardware simulations increases, the modeling of actual events becomes more realistic. These methods can be used to augment actual testing or permit the testing of components to be waived during the validation process, depending upon the level of confidence in the hardening predictions.

The level of sophistication of software can be increased by incorporating artificial intelligence techniques. Expert systems can be used to enhance the decision making capabilities of a program. By incorporating the knowledge of "expert individuals" into a rule base used by the program, the resulting decisions incorporate the human expertise. Neural networks can be used to predict future trends based on past "learned" data. The result will be an approximation of the actual answer. For predictions dealing with uncertain events or data, fuzzy logic can be utilized. Fuzzy logic can be embedded into other applications to provide more accurate predictions.

2.6 DATABASE DEVELOPMENT AND CONFIGURATION MANAGEMENT OF APPLICABLE STANDARDS AND SPECIFICATIONS.

As the regimens and protocols are developed, a database will be built of existing protocols, test methods, analysis tools, simulators, test facilities, specifications, etc. Initially, an expenditure of time and resources will be required to gather adequate documentation on these items. The database will only need to be updated as new protocols are developed. Configuration management of the database is an on-going process with its associated expenses, and must be continued as long as the data base is maintained. Program Office personnel will then have the opportunity to select from this array of tools to build an acceptable survivability program which will address the required confidence limits. If the necessary tools are not available, then they must be developed by the time they are needed. Otherwise, the program schedule can be impacted and the survivability validation will become the critical path in the program schedule.

2.7 SURVIVABILITY CONFIDENCE LIMITS.

The type of protocol selected for use will depend on the confidence limits required for the system survivability. Sufficient testing of the system in the expected environment with the anticipated threats can assure the system survivability. Needless to say, actual testing against most threats cannot be performed due to the difficulty of the test or the severity of the testing to the environment, such as in nuclear explosions. Thus analyses, simulations, preliminary testing, or detailed testing (such as UGTs) must be used. If the system can undergo an underground test, the results will usually be the most realistic, although even a UGT will not totally

emulate an atmospheric event, e.g., radiation pulse width, x-ray spectrum, etc. The protocols to perform a UGT may be relatively simple, but the actual performance of the test is one of the most expensive means of survivability validation. Since nuclear testing is infrequent and expensive, other methods can be used to provide basic confidence in the survivability. The fidelity of the other methods can be refined by comparison with nuclear test data. Large system-of-systems testing can only be performed on smaller segments, so survivability validation of the entire ensemble must be performed by analysis or simulation. The greater the confidence in the result, the more extensive the protocol validation becomes and the greater the development cost.

2.8 COST OF PRODUCING AND VALIDATING NEEDED SOFTWARE ANALYSIS TOOLS.

Protocols can utilize various computer and analytic simulations as part of their structure. Many times new modules can be inserted into the old codes to provide enhancements to validate the survivability of the new component. Otherwise, a new code will need to be developed to perform the required functions. In addition, the software utilized must be validated to assure its usefulness in providing suscepti-bility validation. Independent of the method that is used, time and resources must be allotted in the acquisition cycle to develop and validate the new software enhancements to the required confidence levels.

2.9 PROTOCOL APPLICATION COSTS.

Once the regimen has been built with protocols selected and adapted for system-specific use by the Program Manager and his staff, the cost of applying the protocols must be considered. The Program Manager must weigh the impact of continuing his organization's present mode of operation versus the impact of imple-menting the protocols outlined in the regimen. Although the present mode of sur-vivability validation operations performed by many organizations may have pro-duced adequate results in the past and may be favored because of familiarity with the procedures, their continued use may be time-consuming and a waste of resources. This is because the old methods have evolved over many years, and due to resistance to change, may not use the latest techniques nor be easily tailored to specific requirements. These factors may cause wasted effort and the possibility of cost overruns, schedule slips, or waivers.

The use of protocols, which utilizes a set of quantifiable processes, alleviates the undesirable results of the previous factors. This is because the protocol baseline will consist of relevant survivability validation and design procedures. They will have been adequately validated, incorporate lessons learned, and be able to be tailored for specific requirements. The protocol approach will permit long term planning, since the costs and schedule can be easily quantified from the beginning of the program to its projected completion.

Recurring cost from program to program will be reduced, because the protocol concept will provide for a dynamic database of validated protocols. This will elimi-nate "reinventing the wheel" for each new program. As new protocols are vali-dated, they will be added to the database, providing the Program Managers with current validation tools and lessons learned from previous programs. Any validation tools needed for the program will be able to be quickly identified to permit rapid projections of the development costs of the tool into the acquisition process. If the tool is relatively inexpensive (such as a short subroutine), the Program Office may be able to absorb the development cost. However, if the tool requires significant

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development cost (such as a simulation facility), a new program may be initiated to develop it. Either way, development costs will be reduced due to the early identification of the needed tools in the planning process.

SECTION 3

ORGANIZATIONAL AND INSTITUTIONAL ISSUES AFFECTING PROTOCOL USE

3.1 INTRODUCTION.

There are several factors affecting the decisions to use protocols. Since they cover various topic areas, they will be considered under the heading of "organizational and institutional" issues. The following sections will discuss a few of these organizational and institutional issues.

3.2 ORGANIZATIONAL RESISTANCE TO ADOPTING PROTOCOLS.

It is "human nature" to be cautious or reluctant to adopt new ideas or to change established procedures. Some of this can be related to the inertia of always having done something a certain way and not wanting to try new methods. However, in the case of accepting the use of protocols, there are several other factors that come into play. Some of the organizations have a "not developed here" attitude and will not utilize products produced by other organizations. This attitude can develop because of a distrust of the other organization's understanding of the problem, based on past "bad" experiences. Sometimes, it is due to the lack of control of the people doing the work and little control on the resulting product. Another reason is a protective attitude where the manager wants to keep the funds for the project within his own organization and keep his people busy, making his department look productive. Unfortunately, this process can be repeated in several agencies, so that there is a duplication of similar efforts. The reduced budgets projected for future years will not allow this type of management to continue. Thus organizations will be forced to tradeoff the merits of continuing with their present means of validation versus using the protocol management process.

The various DoD components have somewhat different requirements for systems developed for land, sea, air, and space. However, there are many common methodology elements that exist between the systems and these have precipitated some of the duplication in the development methodologies. By incorporating all the validated hardening techniques into a database, the Program Managers in each agency can select the best techniques for their system.

3.3 EFFECT OF BUDGET FLUCTUATIONS.

Budget fluctuations can have a serious impact on the use of protocols. If the world situation is stabilized, the budget will reflect cutbacks in defense. The importance of the project to the national defense will determine the amount of funding it receives. If the anticipated funding level is not provided for the project; the program can be stretched out over a longer time period, various segments of the project can be delayed until later in the program, protocols producing a lower hardness confidence level may need to be used to keep within the budget, or the program or parts of it could be canceled. A de-emphasis on the project reflected by a reduction of funding will necessitate appropriate changes in the protocols used for the program. If aggression by a country on its neighbors is in process or being threatened, the defense budget will reflect the severity of the situation and the program can be accelerated. In such a case, more efficient (but probably more costly) protocols will need to be considered to meet the schedule constraints. Any of these options will require a reevaluation of the protocols and reviews/approvals by the acquisition authority.

3.4 DIFFICULTY IN UTILIZING FACILITIES.

Simulation or test facilities can be difficult to use as validation tools because of the problems involved in fully utilizing them. Some of these problems can arise from the reluctance of agencies to use other facilities. As mentioned earlier, this can stem from a "not developed here" attitude or a sense of "loss of control "for the testing by permitting other agency involvement in the tests. Other situations impacting utilization include: domination of the facility by the operating agency to test their own systems, unavailability of facility due to heavy test schedule or repairs, bumping of projects due to other high priority projects, or the required capability has not been implemented by the time the program needs it. These types of problems can be devastating to the system test schedule even to the extreme of missing a milestone. Thus, the Program Office must have contingency plans available. The protocol database could assist in this process because it will have all the options readily available for review.

3.5 THREAT INTERPRETATION.

Although the threat environments are defined in the STAR, applicability of each of the components in a system to those threat environments must be assessed. This is true particularly for distributed systems having land, sea, air, and space subsystems. These systems will require procedures that are different for the various components in the system.

Infrequently, the intelligence agencies may not agree on the interpretation of the intelligence data alluding to the threat. This can lead to heated discussions between agencies with the result being that the threat scenario may have a component missing from it. If that missing component is later deemed a valid threat or if a new threat was not identified in the original STAR, then the protocols will need to be modified or new ones developed to assess the hardness of the system against the new threat. The primary danger of this process is that survivability technology requirements may be missed, which will diminish the appropriate lead-time needed for the technology development. This can cause schedule slippages or the inability to assure the survivability of the system to the threat.

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SECTION 4

CONSIDERATIONS FOR SELECTION OF TYPE OF PROTOCOL

4.1 INTRODUCTION.

The survivability validation regimen and protocols used for a specific system development will be updated as the acquisition process progresses through the various milestones and phases. The regimen and protocols may be modified in conjunction with the modifications to the TEMP. The protocols may become more comprehensive with each phase until the system is deployed. For example, a protocol developed for Phase III (Production and Deployment) and Phase IV (Operations and Support) will stress the hardness maintenance and hardness surveillance of the operational system to assess its continued survivability. Typically, more detailed protocols will be used during the validation testing of the system to meet the survivability requirements. The confidence level of the protocol will be determined by the system requirements and the extent of validation of the protocol. Hopefully, all the protocols will be available and validated prior to the time they are required for the program. The Program Management Team will select the appropriate validated protocol commensurate with the TEMP requirements and program financial/schedule constraints. Several of the factors the program management personnel must consider in selecting protocols are listed below and described in the following paragraphs:

(1) availability of technology;
(2) schedule;
(3) size/complexity of system;
(4) fidelity of validation and confidence limits desired;
(5) type of deployment environment;
(6) fiscal constraints imposed on program;
(7) availability of validation tools;
(8) system criticality.

4.2 AVAILABILITY OF TECHNOLOGY.

Updated or new protocols may be needed if a new technology is used in the production of the system under development or new technologies are utilized in performing old processes. Protocols using existing simulators or analysis tools may be able to be upgraded to accommodate the new technology survivability validation requirements. The technology may not be available to develop the necessary protocols or modifications. Therefore, the need for protocol development should be identified as soon as possible in the acquisition cycle. If the protocol requires the development of a new capability that will take longer than the projected program survivability validation schedule, other means must used to provide the survivability validation. These can consist of utilizing other less effective test methods, software simulations, or various analyses to provide a level of confidence of the system hardness. The lower confidence limits available from these methods must be weighed against the impact to the program of waiting to use the newly developed facility.

4.3 SCHEDULE.

Protocol selection is affected by the program schedule. Trade-offs between the use of simulators, analyses, or test facilities must be made to accommodate the

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program's schedule. Some of the factors to be weighed in this decision are: time involved to conduct tests, time required to develop or modify test facilities or analysis tools, availability and cost of a facility, how many facilities must be utilized in the validation process, availability and cost of analysis tools or simulators, types of analysis tools or simulators needed, ease of obtaining analysis tools or simulators, and confidence in the obtained hardness levels. Depending upon the system complexity, many times a combination of analyses/simulations and testing provide the best compromise between survivability validation time and cost factors.

4.4 SIZE/COMPLEXITY OF SYSTEM.

The size and complexity of the system determines the methods to be used for survivability validation. An expensive test facility should not be used to evaluate a simple system that can be analyzed just as effectively with an inexpensive computer analysis code. Alternatively, a simulation or analysis method may need to be used to avoid costly modifications to a test facility to test an oversized system. In many cases the survivability of an oversized system or one that has components separated by a large distance can only be validated by simulations or analysis methods.

4.5 FIDELITY OF VALIDATION AND CONFIDENCE LIMITS DESIRED.

The degree of hardness validation required will determine the fidelity of the validation tool. In addition, increasing the hardness confidence bound will usually increase the cost of implementation of the protocol. For instance, the greater the confidence desired from a software program, the more fidelity the program requires (this typically is manifested in more lines of code or code testing with their associated costs). Higher confidence levels often imply more tests, accompanied by increased costs and impacts on the schedule.

4.6 TYPE OF DEPLOYMENT ENVIRONMENT.

The deployment environment, including the threats and operational scenario, is defined in the mission need determination and initial concept studies. To optimize program resources, protocols should not be selected that will validate more survivability areas than are identified in the TEMP requirements. However, the associated validation protocols should be tailored to provide optimum use of the method. For example, as mentioned earlier, it is already recognized within the DoD that some electromagnetic codes used for predicting electromagnetic compatibility can be used to assist in predicting nuclear effects. Instead of using the full capability of a code to predict intra-system compatibility, inter-modulation, cross-modulation and radiated effects, the code can be tailored to use only the radiation effects for EMP predictions.

4.7 FISCAL CONSTRAINTS IMPOSED ON PROGRAM.

Monetary restraints on the program can be a key driver in protocol selection. This is because the Program Manager must be prudent in his selection of protocols to permit the maximum efficiency of survivability confidence with the minimum expenditure of resources. This means that if there are two protocols that can perform a validation function and one has a hardness confidence limit 5% greater than the other, but it costs twice as much to perform, the tendency will be to use the least expensive method as long as the hardness confidence limit is acceptable.

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The Program Manager must be aware of fiscal constraints in the protocol selection process. Although there is some flexibility in the use of the money allocated for the program, the Program Manager must make sure not to exceed the amount projected for the tasks and he must stay within the proposed expenditure rate as much as possible. As a result, a protocol that can be performed within the monetary and schedule constraints will be preferred over a protocol that will extend the schedule or exceed the funds allotted for the task. This is because the budgetary process cannot always be depended upon to provide additional funding in subsequent years.

4.8 AVAILABILITY OF VALIDATION TOOLS.

Once a protocol is selected, the availability of the tool to perform the survivability validation must be commensurate with the program schedule. If the tools are not available, then the need for a development program must be identified. If the tools cannot be produced within the required timeframe, either alternate methods of validation must be found, the survivability validation requirement must be relaxed, another protocol may be considered for use, or a program slip may occur. Program slips with their corresponding cost overruns are not looked upon favorably by the acquisition authority and must be avoided. Section 4 discusses more of the issues affecting validation tool availability.

4.9 SYSTEM CRITICALITY.

The importance of the system to the national defense will determine the level of support provided by upper level management. Top level management support can also expedite the scheduling of facilities and simulators. However, expedited schedules usually mean elevated implementation costs.

4.10 TEST-BED/SIMULATOR/ANALYSIS TOOL AVAILABILITY.

The system being developed by a Program Office must have its survivability validated to a specified hardness level. This is done by utilizing validated analysis techniques to predict the system hardness levels, running established simulations to provide assurance of the system survivability, or performing AGT or UGT testing on the system using proven test methods. The availability of these tools is imperative to the success of the survivability validation program. As mentioned before, if the various tools necessary to perform the validation are not sufficient to perform the task or they are not in existence, a development program for these validation tools must be initiated. As a result, all the factors mentioned earlier impacting the development of a new protocol must be considered.

The Program Manager must evaluate the validation tools available to perform a specific protocol. Some of the factors that must be considered include: the sufficiency of the validation tool capabilities, prediction fidelity, scheduling of validation facilities, cost of validation tool use, and contingencies.

The validation tools must have capabilities that are consistent with the system to be analyzed. The tools must provide the proper level of confidence in the hardness of the system to assure its survivability in the projected threat environment. In addition, the fidelity of the tools must be evaluated to ensure that the tools provide hardness assurance to the proper confidence level. A confidence level excessively higher than that required for the system is generally indicative of increased costs associated with the use of the validation tool. For example, scheduling an under-

ground test for piece-parts that already have a wealth of data accumulated on them would be a waste of program resources. Even though the UGT would provide the required confidence levels, the same level of confidence could be provided by AGTs or analyses and there would be substantial reductions in difficulty and cost. Conversely, analysis of a new component using a technology never tested before, or having suspected modes of failure different from what can be induced by AGT, would probably not provide the required confidence levels, and UGT testing may be required (depending upon the importance of the system).

In this evaluation process, the Program Manager must consider contingencies if the validation tool is not available. Other options must be considered in case a simulator or test facility is not available for use at the required time in the program schedule. There may be scheduling difficulties because of excessive use of a facility, other higher priority systems having precedence and bumping previously scheduled programs, reluctance of organizations to use outside facilities, difficulty in coordinating between DoD components, changes in U S policy regarding nuclear testing, etc. For example, an acquisition program may have several key subsystems scheduled for UGT testing when the United States initiates a ban on all nuclear testing. The protocol the Program Manager used for the survivability validation should have indicated alternatives to UGT testing that could be implemented and the Program Manager should have provided contingency plans.

The Program Manager must balance all of these factors to optimize the use of the validation tools' capabilities. The survivability protocols must provide the Program Manager the flexibility to tailor his program to meet the desired goals.

SECTION 5

DEVIATIONS PRECLUDING ADHERENCE TO VALIDATED PROTOCOLS

5.1 INTRODUCTION.

During the life-cycle of a program, situations can arise that preclude the adherence to the survivability validation regimen or protocols and may require deviations to the original protocols. The approved deviations must be incorporated into the TEMP for proper disposition. Deviations can be the result of several factors, some of which are listed below.

5.2 POLITICAL DECISION IMPACT ON SYSTEM DEVELOPMENT.

The world situation may dictate that the system under procurement be expedited as a result of tense circumstances. In contrast, diminishing threat could cause the redirection of defense funding to social programs. This would necessitate an evaluation of all applicable programs to stretch their schedules or to be considered for cancellation.

5.3 WAIVERS TO PROTOCOLS.

During the system development cycle, waivers to the proposed protocols may need to be granted due to various circumstances. The Program Management Team can recommend that further analysis or testing be waived and deviations made to the original protocols for many reasons. Two reasons are: sufficient survivability design margins shown by analysis or simulation during the early phases of the development cycle and comparisons between present system components to already tested and fielded components, which indicate that the survivability margins are high. Before these deviations can be granted, it must be shown that the hardness confidence limits are surpassed. In most cases these options will be part of the protocols, but they are listed here for completeness.

Although the protocols should have contingencies to handle most situations, the ones most likely to not be adequately covered are changes in the funding and schedule. As these vary, various trade-offs need to be performed which may result in waivers to the protocols. The fluctuations can come about due to the unavailability of proper validation tools, an acceleration of the program, a de-emphasis of the program resulting in a stretching of the schedule or elimination of requirements, overruns in other portions of the program causing shortfalls for survivability validation, etc. The magnitude of these changes cannot be anticipated in advance, so waivers to the original protocols will be required after the proper procedures to handle the situation have been determined and associated reviews/approvals made by the acquisition authority.

5.4 CHANGE IN THREAT SCENARIO.

The STAR details the accepted threats for the program. The STAR is established early in the program cycle and is refined as required. However, if a new threat is uncovered due to the development of a new technology or different use of an old technology, the system development cycle will be impacted. An assessment of available technologies must be made to determine if a new technology development program is required to perform the survivability validation process. Any new technologies that are required must be identified as soon as possible to assure their

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timely implementation. If the changes in the threats are identified early in the development cycle, adjustments to the program can be made much easier than when the system is nearing production. In that instance, a major modification or preplanned product improvement program may be required. In either case, additional protocols must be added to the survivability regimen to provide adequate hardness assurance.

5.5 ACQUISITION AUTHORITY REDIRECTION.

Protocols can be impacted by changes in direction by the acquisition authority. These changes cannot be anticipated in the original protocols and must be handled on a case by case basis by modifying old protocols or initiating the development of new ones. In most instances, the acquisition authority redirection is a result of Congressional pressure or a change in the acquisition strategy. Any of these will invariably impact the schedule and resources required for the procurement, generally with increases in both.

5.6 DIFFICULTY OF PROTOCOL PROCEDURE ACCEPTANCE.

Some agencies may have a reluctance to use the established protocol procedures. This inertia may result in an adherence to old inefficient methods which can cause unnecessary stress on the program funds and schedule. Potentially, greater efficiency could be obtained by using a survivability regimen and its associated protocols, which consist of validated hardening techniques. Thus the agencies and Program Managers must be convinced that using this management technique will be beneficial. Acceptance of the protocols can be assisted by using validated hardening techniques and making the protocols general enough for use by all agencies, but be versatile enough to handle any special requirements posed by the operational environment. For example, the protocol for the nuclear hardening of a missile must be general enough to cover missiles developed by the three Services. However, it must contain sections specific enough to handle any special operational requirements imposed on each Service's missile.

5.7 SCHEDULE SLIPS.

Changes to the original protocol resulting from any of the deviations mentioned previously can cause a schedule slip if they cannot be enacted quickly enough in the acquisition cycle. This will result in reviews and inquiries being held at the appropriate level. Depending upon the importance of the project, these reviews can be held by the acquisition authority, or if a milestone is missed, reviews can be held at the Congressional level. Not meeting the schedule can cause major impacts to the program such as major cost overruns and delays in fielding the system. In the extreme of missing a milestone, the resulting investigations could result in a major cutback of the system or cancellation of the program. Thus, the regimen and protocols must be flexible enough to permit rapid redirection of the effort to satisfy the new survivability requirements.

SECTION 6

PROTOCOL ADVANTAGES

The use of regimens and protocols is a proactive management approach for survivability validation. The previous discussions have primarily pointed out some of the difficulties involved in protocol development. This section will address some of the advantages of using protocols.

As mentioned in earlier sections, the Program Manager is responsible for the survivability of the system during its entire life cycle. The regimen and protocols are a valuable management approach to help the Program Manager achieve survivability validation in an efficient manner. Although protocols are presently used in various segments of the acquisition cycle, the proposed management method would use a regimen and protocols throughout the program. This departure from previous management methods permits greater flexibility in establishing a survivability validation program. The survivability program is tailored to the acquisition schedule and allotted resources. The selection of protocols is performed by the Program Management staff. The staff will more readily accept the procedures and be committed to the project because they have been intimately involved in developing the survivability program. Using the protocols permits effective cost/schedule trade-offs to be made during the planning phases to help develop an optimum strategy for the survivability program and provides documentation of the survivability validation process.

Since the protocols are developed for general use, the various DoD agencies can choose the protocols that best suit their purposes. The protocols will be documented in a database and be readily accessible. In addition, there will be many protocols with varying hardness confidence levels to permit efficient use of the available resources. This management procedure will reduce the costly duplication of methodologies by each DoD agency. The protocols can have sections for the specific needs of a DoD agency. Because of this modularity, the protocols can be used by many different programs without further protocol development expense. For instance, the protocol for a UGT for a communications subsystem could have sections of the protocol which would describe the specific hardness validation procedures for land, sea, air, or space systems. This would permit the various DoD agencies to use the same basic protocol for any communication system, but the specific implementation for an operational environment (land, sea, air, or space) would be located in different branches of the protocol. The basic protocol format would capitalize on the similarities of protocols already developed by the various agencies.

To permit a more versatile survivability program, the protocols will be written to allow deviations in the implementation of the regimen and protocols without extensive disruption to the survivability program. Since the regimen and protocols are tailored for each phase of the development cycle and updated to reflect developments in the acquisition, there is a smooth transition between the acquisition phases. Because the protocols will already be validated, the various review boards can readily determine if the selected procedures are adequate to perform the survivability validation. Approval cycles are made easier, since the entire survivability program life-cycle is available for review, with the major detail centered on the development phase under review. The subsequent reviews are expedited because the basic Program Plan has already been described at the previous reviews and only changes or further detail would be added.

Early approval of the protocols using the established procedures and criteria provide many advantages to the Program Office and acquisition authority, because each has a good idea of the survivability implementation plan well in advance of its implementation. This procedure optimizes feedback to the acquisition authority regarding deficiencies in technologies or protocols to speed up any development programs that are required. It also permits Program Office personnel to plan for long lead items in the development cycle.

SECTION 7

ISSUES

7.1 INTRODUCTION.

The previous sections have addressed many of the factors involved in developing and using protocols. It has been shown that the use of this management technique will permit greater efficiency in the survivability validation process of a system. In addition, using protocols will provide extensive savings of time and resources during the program life-cycle. This is due primarily to the use of pre-approved systematic methods to obtain the prescribed hardness confidence levels required for the system deployment.

7.2 SURVIVABILITY ISSUES.

There are several survivability issues that must be considered during the life-cycle of a system. Some of these are presented in Table 7-1, which provides a list of nuclear survivability actions required during the life cycle of a system. These issues must be sufficiently addressed by the regimen and protocols selected for the survivability validation program. An effective management procedure must address each of these issues. As a result ,the regimen and its associated protocols would be used at the onset of the program and become more detailed and comprehensive with each milestone. The associated protocols for each regimen will have established procedures, tests, or analyses for each system element requiring survivability validation.

Protocols must account for the levels of system integration from piece-part to system-of-systems. Different validation protocols may be required at each level. Table 7-2 provides the hierarchy of level of integration of a system-of-systems, which is defined as the highest level of integration. Figure 7-1 depicts how the protocols for the system utilize the tools and procedures appropriate for the hierarchy level. The results of the protocols from piece-parts to the system are integrated to provide the required level of survivability for the system.

The protocols must sufficiently address hardness assurance, hardness, maintenance, and hardness surveillance to have a successful survivability program. These programs are designed to ensure that the hardened design is produced correctly, assure that the hardened features are maintained to design specifications, and make sure that the hardening features are monitored to determine if they have degraded. The protocols must show that the following three elements have been adequately addressed in the survivability validation program:

(1) Hardness assurance assures that the hardness features are produced as designed;

(2) Hardness maintenance provides instructions to preserve the hardened design during operations, maintenance, and logistics or support activities;

(3) Hardness surveillance examines the fielded equipment to determine whether the hardening features of the system have been degraded. In addition, an assessment is made of the hardness maintenance program to determine if it is adequate for maintaining the system.

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Table 7-1.   Survivability actions during system life cycle.

MILESTONE DECISION POINT	SURVIVABILITY ACTIONS
Concept Studies Approval	• Establish survivability requirements
Concept Demonstration Approval	• Verify survivability requirements • Establish survivability criteria and identify in Operational Requirements Document • Include key survivability objectives in Concept Baseline • Test and Evaluation criteria included in Test and Evaluation Master Plan (TEMP). • Identify initial survivability technology shortfalls • Facilities characteristics tracked through the Integrated Logistics Support Plan (ILSP)
Development Approval	• Identify critical items requiring tests and include in TEMP • Include survivability objectives in the Development Baseline, System Specification, and ILSP • Develop hardness assurance, maintenance and surveillance programs and include in ILSP • Address survivability issues in Integrated Program Summary
Production Approval	• Assess how well survivability objectives have been met and include results in initial Production Report • Resolve any survivability issues • Include survivability objectives in Production Baseline • Complete development and implement hardness assurance program and HM/HS plans
Major Modification Approval	• Review engineering change proposals for survivability issues • Support hardness assurance program

Table 7-2. Hierarchy of levels of integration of a system-of-systems.

Level of Integration (Highest to Lowest)	Examples
System-of-Systems (SOS)	GPALS, Trident, Theater Missile Defense
System element (SE) level	Constellations of a particular satellite, e.g., Brilliant Pebbles
System element platform (SEP) level	A radar, satellite, an individual Brilliant Pebble, a missile
Subsystem level	Power subsystem of a satellite, seeker of a kinetic kill vehicle, post-boost vehicle guidance system
Component level	Individual electronics boxes, lenses, mirrors
Part/material level	Baffle materials, piece parts

The regimen of protocols is not intended to be used as an inflexible set of procedures to be implemented for all systems. Instead, the regimen is tailored for a specific procurement and becomes a living management tool that is enhanced as the acquisition proceeds. In addition, the protocols cover a myriad of analysis methods, simulations, and tests that can be selected to validate the survivability of the system. Each protocol has a certain level of risk and confidence associated with its use. This permits the Program Manager flexibility in selecting the optimum set of protocols to achieve the desired level of survivability confidence commensurate with the mission requirements, program schedule, and financial constraints.

A "proof-of-hardness" cannot be obtained without subjecting the system to the true threat environment and assessing the results of that environment on the system. For many environments actual testing is not practical, as is the case for assessing nuclear effects on large distributed systems. Thus, test and analysis play complementary roles in validating system hardness. Comparison of test data with analytical predictions provides confidence in the analytical approach and under-standing of the system. In turn, the analysis can be extrapolated to the threat envi-ronment with increased confidence. The validation process is then an iterative process in which the principles of good engineering practice, the results of analytical calculations, simulations, and test data are used to assess system hardness with the level of confidence dependent on the methods used.

Protocol selection permits trade-offs between analysis and testing. During the initial design phases, analysis will have a primary role with support from empirical data. As the development proceeds from the design phase to hardness validation and operation, testing will assume a more dominant role with support from analysis. However, in many cases (as in system-of-systems and ground-based facilities) a full test simulation is not possible, nor is a complete analytical evaluation possible due to the vast complexity of many systems. Hence, throughout all phases of the system's
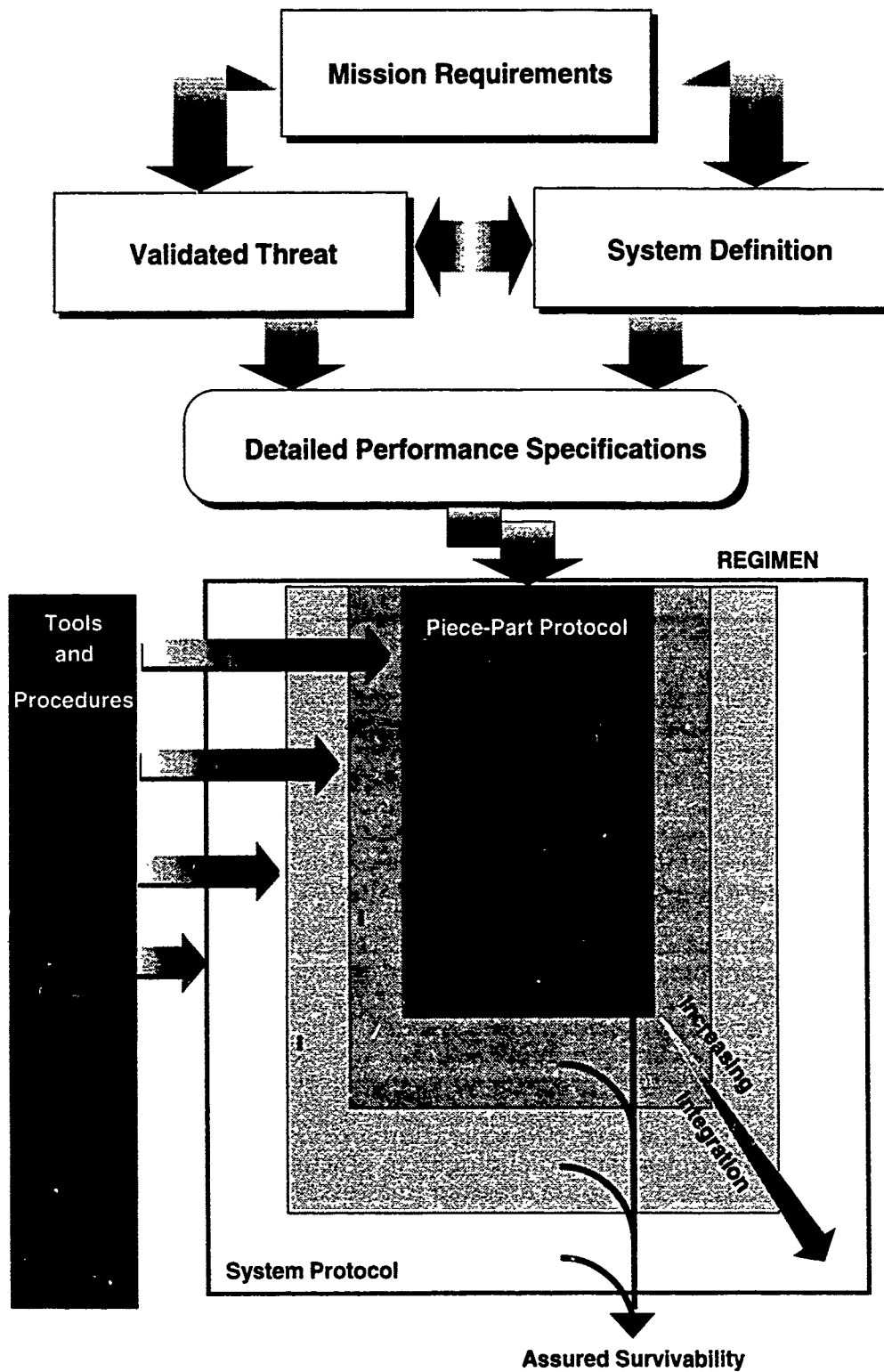
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Figure 7-1. Systems survivability validation process.

life-cycle, a balance between testing and analysis is used to evaluate the survivability.

Care must be exercised when implementing hardening measures because the hardening for one threat can impact the effectiveness of other related threats. One example is the electromagnetic (EM) disciplines of electromagnetic compatibility, electromagnetic interference control, lightning protection, TEMPEST control, and electromagnetic pulse (EMP) protection. In some cases, protection against one effect may also provide protection against another, but often conflicts may arise between the protection practices utilized for these EM effects. The appropriate protocol should indicate this interrelationship. For example, it is already recognized within the DoD that it is advantageous to combine all the electromagnetic effects into a few standards and requirements. Thus, the protocols utilized for EMP protection can alert the user to the practices used for protection from the other EM effects. However, the EMP protocol does not have to incorporate these practices from the other EM disciplines. This encourages the development of a good system design which incorporates integrated electromagnetic effects protection techniques, whenever practical.

7.3 TRADEOFF ISSUES.

The use of regimens and protocols will help the Program Manager and his staff perform quantitative tradeoffs to assist in the planning stages and updating of a system's survivability validation program throughout its life cycle. Table 7-3 lists several of the cost trade-off factors that can be considered. The results of these analyses permit flexibility in selecting the optimum set of protocols to achieve the desired level of survivability commensurate with the mission requirements, program schedule, and financial constraints.

During the course of the protocol pilot study, example quantifications of these factors for a specific scenario will be performed to describe to the community the cost and time issues associated with protocols. In addition, a basic quantification of the resources required to create, update, maintain, and establish configuration control of the protocol database should be performed. This will provide decision makers with estimates of the resources required for implementing the protocol management technique.

Table 7-3. Potential protocol trade-off factors.

| Confidence limits |
| Detail/fidelity of protocol |
| Protocol updates (for modified or new systems) |
| Implementation factors |
| Availability/accessibility of tools |
| Utilization costs |
| Validation tool improvements |
| Waivers |
| Schedule |
| Cost analyses |
| Application costs |

7.4 OTHER ISSUES.

There are several outstanding issues that will be considered during the development of the protocols. These are listed below:

(1)   An adequate list of commercial and government test facilities, standards, handbooks, data items, and available analysis/simulation codes must be updated and configuration control must be imposed and maintained for as long as the database is utilized. This will be the basis set for the protocols and will be used by Program Office personnel in developing the survivability regimen. The basis set will consist of only validated protocols. Thus, community acceptance of the validation techniques will be easier, because the protocols are already in general use;

(2)   A determination must be made as to the level of generality of the protocols required to make a viable set of protocols for all types of situations. Protocols from each of the DoD agencies should be used and various techniques specific to a particular agency must be incorporated. This will also assist in acceptance of the protocols;

(3)   The resistance of agencies to adopt a new management technique must be addressed. This can be accomplished by informing the community through conference papers, technical meetings, and reports addressing the advantages of using protocols. Support for the new management technique can be obtained by inviting the interested agencies to workshops to assist in developing some of the protocols. The protocol introduction process must show the Program Managers that they will be provided with enough information to perform efficient cost/confidence trade-offs during protocol selection. In addition, it must be shown how the protocols will help the Program Office with the hardness assurance, hardness validation, and hardness maintenance/hardness surveillance (HM/HS).

(4)   Investigations are required as to the best methods available to validate the survivability of a system that can't be tested, such as a system that has widely separated components. Once the techniques have been established, the protocols can be developed.

SECTION 8

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Appendix
List of Abbreviations

AGT	-	Aboveground Test
CTP	-	Critical Technical Parameters
DoD	-	Department of Defense
EM	-	Electromagnetic
EMP	-	Electromagnetic Pulse
GPALS	-	Global Protection Against Limited Strikes
HM/HS	-	Hardness Maintenance/Hardness Surveillance
ILSP	-	Integrated Logistics Support Plan
MAOPR	-	Minimum Acceptable Operational Performance Requirements
SE	-	System Element
SEP	-	System Element Platform
SOS	-	System-of-Systems
STAR	-	System Threat Assessment Report
TEMP	-	Test and Evaluation Master Plan
UGT	-	Underground Test
U.S.	-	United States

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